The US Army and the Emergence of Unmanned Threats

A Monograph

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2016

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
07-04-2016	Master's Thesis	July 2015 - April 2016

4. TITLE AND SUBTITLE

The US Army and the Emergence of Unmanned Threats

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

MAJ Michael J. Predny,
US Army

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

School of Advanced Military Studies
ATTN: ATZL-SWD-GD
Fort Leavenworth, Kansas 66027-2134

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

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15. SUBJECT TERMS

Air Defense, Cruise Missiles, Unmanned Aircraft Systems, Proliferation

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
(U)	(U)	(U)	(U)	47	19b. TELEPHONE NUMBER *(Include area code)*

Reset

Monograph Approval Page

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Abstract

The US Army and the Emergence of Unmanned Threats, by MAJ Michael J. Predny, 47 pages.

The proliferation of unmanned technology, both unmanned aircraft and cruise missiles, challenges the decades-long assumption that the US Army will operate under conditions of air superiority. The expendibility of unmanned platforms and lack of risk to pilot and crew change the threshold of risk an adversary is willing to accept. While unmanned threats perform many of the same roles as manned aircraft, contemporary and counterfactual case studies of Hezbollah and Chinese employment show that the relative advantages of unmanned threats significantly increase the probability and severity of adversary action through the air. Examination of the lessons learned operating under the threat of air attack in World War Two indicates several possible mitigations of this increased risk. Identified lessons in passive defense from World War Two remain relevant and were retained in Army capability and doctrine. However, lessons in organizing active defense and shaping conditions to protect US ground forces have been forgotten or are in need of adjustment to accommodate the emerging unmanned threat.

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Acronyms

A2/AD	Anti-Access/Area Denial
AAA	Anti-aircraft Artillery
ADP	Army Doctrine Publication
ADRP	Army Doctrine Reference Publication
ATP	Army Techniques Publication
GPS	Global Positioning Service
IDF	Israeli Defense Force
JP	Joint Publication
LACM	Land Attack Cruise Missile
MTCR	Missile Technology Control Regime
RAND	Research and Development Corporation
TP	Training and Doctrine Command Pamphlet
UAS	Unmanned Aircraft System
US	United States
WMD	Weapon of Mass Destruction

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Introduction

For decades US land forces have operated under the assumption that the air component will provide an umbrella of air superiority sheltering ground forces from air and missile defense threats. The emergence and proliferation of new technologies and their employment methods challenge this long standing assumption in future conflicts. If proven wrong, are US ground forces prepared to operate without the guarantee of air superiority provided by the other services?

Joint Publication (JP) 3-01 defines air superiority as "that degree of dominance in the air battle of one force over another that permits the conduct of operations by the former and its related land, maritime, and air forces at a given time and place without prohibitive interference by the opposing force's air and missile threats."[1] If emerging threats such as cruise missiles unmanned aircraft prove difficult to detect and counter it will become more difficult for the air component to prevent prohibitive interference of land forces from the air.

The US military has repeatedly demonstrated the effectiveness of cruise missiles; however, the United States and its allies are not the only countries to maintain cruise missiles in their inventory. Nearly seventy countries have cruise missile programs and weapons development programs in additional countries could be concealed within aircraft production.[2] Cruise missiles themselves are difficult to defeat. High speed, low altitude, terrain following flight profiles can drastically reduce the warning time to potential targets if the cruise missile is detected at all.

During the 2003 US-led invasion of Iraq, the Iraqi military launched five HY-2 Seersucker anti-ship cruise missiles that had been converted to a primitive land attack capability.

[1] Joint Publication (JP) 3-01, *Countering Air and Missile Threats* (Washington, DC: Government Printing Office, 2012), I-2.

[2] Dennis M. Gormley, *Missile Contagion* (Westport, CT: Praeger Security International, 2008), 47-55.

Although ineffective at striking their targets due to poor accuracy, seemingly none were detected by US ground-based or airborne sensors. With at least one targeting the Marine Corps headquarters at Camp Commando in Kuwait, the potential for cruise missiles to prohibitively interfere with ground forces is apparent.[3]

Unmanned aircraft also challenge US air superiority. As many as eighty-seven countries have unmanned aircraft system (UAS) programs.[4] Often flying low, slow profiles, UAS are difficult for sensors to discriminate from other clutter such as terrain, ground traffic, or even birds in flight. Optimized against high performance aircraft, many air defense systems potentially filter out UAS detections altogether.[5] Undetected UAS can be used to surveil US forces, direct targeting with other weapon systems or conduct an attack itself if capable.

UAS can be employed in a variety of roles with minimal training and supporting infrastructure. In 2006, Hezbollah fighters employed three Iranian-designed UAS against the Israel.[6] Although designed primarily as a surveillance platform, the Ababil is capable of carrying a forty kilogram high explosive warhead, converting it into a "poor man's cruise missile" capable of lethal effects against ground targets. While Israel defeated the individual aircraft, the relative low cost of UAS could allow a regular or irregular adversary to overwhelm air defense systems through sheer numbers used in an attack role.

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[3] Dennis M. Gormley, "Missile Defence Myopia: Lessons from the Iraq War," *Survival* 45, no. 4 (Winter 2003): 61-86, accessed 16 September 2015, www.tandfonline.com/doi/pdf/10.1080/00396330312331343586.

[4] Guy Taylor, "U.S. Intelligence Warily Watches for Threats Now that 87 Nations Possess Drones," *Washington Times*, 10 November 2013, accessed 28 September 2015, http://www.washingtontimes.com/news/2013/nov/10/skys-the-limit-for-wide-wild-world-of-drones/.

[5] Matt Tedesco, Tom Arnold, and Christopher Lowe, "The Future Challenge to US Air Superiority," *Fires* (March-April, 2014): 16-17, accessed 7 November 2015, http://sill-www.army.mil/firesbulletin/2014/mar-apr/mar-apr.pdf.

[6] Benjamin S. Lambeth, *Air Operations in Israel's War Against Hezbollah* (Santa Monica, CA: RAND Corporation, 2011), 130-133.

If emerging air threats and their methods of employment challenge the assumption that ground forces will operate under air superiority, what are the implications for Army air defense in future conflicts? This monograph investigates if proliferation of air and missile threats requires adaptation by the US Army to successfully operate under these new conditions. The first topic this monograph addresses is the extent to which cruise missiles, UAS, and their methods of employment challenge US air superiority. This requires a study of current and emerging capabilities of air and missile threats and their employment methods. This monograph then employs two case studies to evaluate the risk posed by unmanned systems to the mission of the US Army. One is the historical employment by an irregular force, particularly Hezbollah. The second is a Research and Development Corporation (RAND) simulation of Chinese unmanned systems employed in a more conventional conflict over the Taiwain Strait. The tested hypothesis is that unmanned threats significantly increase the threat to the US Army mission.

After establishing a better understanding of how proliferation of air and missile threats contest US air superiority, an additional historical case study is used to study ground operations under such conditions. This third case study is taken from the European theather of World War Two during which air superiority was often challenged. In particular, the successful US defense at the Remagen bridgehead will be examined to determine how active or passive air defense of ground forces evolved to succeed without the guarantee of air superiority and evaluate whether those lessons learned can be applied today. The hypothesis is that many lessons from World War Two have been forgotten in the decades without a credible threat, and they still apply today.

Chapter 1: Identifying the Hazard

The danger of adversary action through the air has existed well before the advent of unmanned systems. The purpose of this chapter is to determine how unmanned technology changes the nature of airborne threats, if at all. Assessment of how risk changes with the proliferation of unmanned technology requires an understanding of unmanned aircraft and cruise missiles, their roles, advantages, and disadvantage as compared to manned aircraft.

A UAS is more than just an unmanned airframe. The term includes the airframe, its payload, launch and recovery equipment, ground control station, and human operators.[7] While unmanned systems perform many of the same roles as manned aircraft, there are distinct differences that justify a separate evaluation of the risk posed to ground forces and their mission. Separating the airframe from the crew and its required life support offers unique advantages and disadvantages to consider when evaluating the risk of UAS to ground forces.

A cruise missile is "an unmanned self-propelled guided vehicle that sustains flight through aerodynamic lift for most of its flight path and whose primary mission is to place an ordnance or special payload on a target."[8] Although similarly unmanned, cruise missiles are considered categorically different than UAS. Whereas UAS are generally reusable, cruise missiles are designed specifically to be expended.

However, development of expendable attack UAS blur the distinction between unmanned aircraft and cruise missiles. The same technologies, such as avionics and precision navigation, enable both. By placing an explosive payload on an unmanned aircraft, and adversary can reproduce a similar capability. Many cruise missile programs have developed out of UAS programs.[9] Due to this blurred distinction, this study investigates the roles, advantages and disadvantages of both.

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[7] Reg Austin, *Unmanned Aircraft Systems – UAVs Design, Development, and Deployment* (Chichester, UK: John Wiley & Sons, 2010), 1.

[8] "Cruise Missiles," Federation of American Scientists, accessed 3 November 2015, http://fas.org/nuke/intro/cm/.

[9] Thomas G. Mahnken, *The Cruise Missile Challenge* (Washington, DC: Center for Strategic and Budgetary Assessments, 2005), 28-30.

Roles

A wide variety of unmanned systems exists with varying degrees of sophistication and capability. The US inventory demonstrates this diversity with systems ranging from the hand-launched RQ-11 Raven to the 32,000 pound RQ-4B Global Hawk.[10] Displaying a breadth of capabilities, different UAS can perform a breadth of mission roles: reconnaissance and surveillance, direct attack, and delivery of a weapon of mass destruction (WMD).

The most common role of UAS is reconnaissance, surveillance, and target acquisition. Carrying a sensor payload as primitive as a cell phone camera or as sophisticated as a synthetic aperature radar, UAS can provide real time intelligence to military commanders sitting in relative safety or identify targets for indirect fires or other weapon platforms. This role has been proven effective both by the United States in recent conflicts, but also by Russian use of UAS in Ukraine. Russian forces repeatedly have used UAS to identify Ukrainian forces and adjust artillery fires, which have caused an estimated eighty-five percent of Ukrainian casualties.[11]

In addition to identifying targets for other systems, UAS can also serve as an attack vehicle themselves just as a cruise missile. The Iranian Ababil is obstensibly a reconnaissance system, but select variants can carry up to forty kilograms in explosive payload, turning a surveillance platform into an expendable guided munition.[12] More sophisticated attack systems

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[10] "Global Hawk (USA)," Military Periscope.com, last modified 1 February 2014, accessed 9 November 2015, https://www.militaryperiscope.com/weapons/aircraft/rpv-dron/w0004373.html.

[11] Sydney J. Freedburg, "Russian Drone Threat: Army Seeks Ukraine Lessons," *Breaking Defense*, 14 October 2015, accessed 17 March 2015, http://breakingdefense.com/2015/10/russian-drone-threat-army-seeks-ukraine-lessons/.

[12] "(Iran) - Ababil," Military Periscope.com, last modified 1 May 2012, accessed 9 November 2015, https://www.militaryperiscope.com/weapons/aircraft/rpv-dron/w0007042.html.

are reusable, carrying separate munitions such as guided bombs or air-to-surface missiles. The Russian Skat, for example, can carry over 2,000 pounds of munitions stored in internal bays.[13]

The Skat is also capable of deliverying the AS-17 anti-radiation missile, giving it a lethal capability against air defense radars.[14] Other lethal UAS are capable of suppressing enemy air defenses. Of particular note is the Israeli-designed Harpy which straddles the definitions of both UAS and cruise missile. Widely exported, the Harpy is an expendable unmanned airframe with an onboard seeker to detect and destroy air defense radars, detonating a warhead just above the target. A specialized attack UAS or cruise missile can eliminate a radar that would otherwise mitigate the risk to ground forces from aerial attack by additional air platforms.[15]

Another specific, yet dangerous application of both UAS and cruise missiles is delivery of WMD. While often more limited in payload than manned aircraft, the availability of UAS and the lack of risk to its operator make them a potentially appealing means for delivering chemical or biological agents. In 2003, Iraq was suspected of converting L-29 trainer aircraft into UAS for such a purpose.[16] While there are many other means of delivering WMD, the use of UAS or cruise missiles in such a role remains a concern.[17]

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[13] "UCAV (Russia) - Skat," Military Periscope.com, last modified 1 September 2010, accessed 9 November 2015, https://www.militaryperiscope.com/weapons/aircraft/rpv-dron/w0008222.html.

[14] Ibid.

[15] "(Israel) – Harpy lethal UAV," Military Periscope.com, last modified 1 June 2013, accessed 9 November 2015, https://www.militaryperiscope.com/weapons/aircraft/rpv-dron/w0004738.html.

[16] Andrew Feickert, *Iraq: Weapons of Mass Destruction Capable Missiles and Unmanned Aeriel Vehicles* (CRS Report No. RS21376) (Washington, DC: Congressional Research Service, 2003), 1-5, accessed 3 November 2015, http://fas.org/man/crs/RS21376.pdf.

[17] Brian A. Jackson et al., *Evaluating Novel Threats to the Homeland: Unmanned Aerial Vehicles and Cruise Missiles* (Santa Monica, CA: RAND Corporation, 2008), 25-26, accessed 8 October 2015, http://www.rand.org/content/dam/rand/pubs/monographs/2008/RAND_MG626.pdf.

Finally, the above mentioned roles can all support an overall challenge to prevent access to a theater, and deny areas for military operations. Combined with other capabilities, attack UAS and cruise missiles can be used to threaten ports and airfields required for military deployment. Similarly, attack platforms, WMD delivery systems, and surveillance UAS combined with indirect fires can support area denial to forces already in theater. Unmanned systems can be used to support anti-access/area denial (A2AD) challenges to external forces.[18]

The roles of unmanned systems are as varied and diverse as the roles of manned aircraft. Uses include reconnaissance and surveillance, attack, suppression of enemy air defense, delivery of WMD, and A2AD. However, it should be noted that these are all roles that can currently be performed by manned aircraft. While UAS may execute these roles in novel new ways, the roles themselves are already familiar. However, the relative advantages and disadvantages of UAS in performing these roles present a new risk to US ground forces.

Relative Advantages

Removing the pilot and supporting subsystems of an aircraft presents several advantages. Requiring less weight for the pilot and life support considerably increases endurance as compared to most manned aircraft. For example, the Global Hawk, an intelligence, surveillance, and reconnaissance platform, can loiter for over twenty-four hours.[19] This increased endurance gives unmanned systems persistence difficult for manned aircraft to provide without multiple sorties or aerial refueling. Flying from a ground control station, operators themselves can rotate to reduce the impact of crew fatigue when operating over extended duration. Not only can the aircraft

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[18] John Gordon and John Matsumura, *The Army's Role in Overcoming Anti-Access and Area Denial Challenges* (Santa Monica, CA: RAND Corporation, 2013), 1-10, 12-14.

[19] "Global Hawk (USA)."

remain on station longer than its manned counterpart, but UAS operators, not confined to the aircraft itself, have more means to mitigate the fatigue of operating for such periods.[20]

Additionally, removing the pilot allows unmanned systems to be considerably smaller which offers an additional advantage in detection and identification. The majority of UAS fly low and slow. Combined with a small radar cross section, UAS are difficult to detect as most military air surveillance radars are optimized to detect high performance fixed-wing aircraft. Low altitude, slow speed, and reduced radar cross section increase the likelihood of an air defense system labeling an adversary UAS as meaningless ground clutter. Consequently, even if radar detects the UAS, the radar system could still filter that detection from the radar operator's display. While cruise missiles fly at considerably higher speeds, their extremely low altitude still challenges ground-based radars.[21] Difficult detection translates into difficulty defeating unmanned threats as less time is available to identify the target and process for engagement by an air defense system.[22]

Not only are unmanned systems more difficult to defeat in the air with traditional air defense sensors, they are also more difficult to defeat on the ground. Small size and mobile launchers allow most unmanned systems to effectively hide from an opponent. Mobile launchers and ground control also free most unmanned aircraft and cruise missiles from fixed airfields, allowing them to continue to operate even if permanent infrastructure is damaged or destroyed.[23]

Although the costs of UAS and cruise missiles vary widely, they still provide a relative advantage in cost. A 2012 cost-benefit analysis found most US unmanned systems not only less

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[20] Jacquelyn Schneider and Julia MacDonald, "Are Manned or Unmanned Aircraft Better on the Battlefield?" *Cicero Magazine*, 16 June 2014, accessed 9 November 2015, http://ciceromagazine.com/features/the-ground-truth-about-drones-manned-vs-unmanned-effectiveness-on-the-battlefield/.

[21] Mahnken, 28.

[22] JP 3-0, A–1 - A–4.

[23] Mahnken, 32.

expensive to acquire, but also less expensive to operate than US manned aircraft.[24] The RQ-11 Raven, sold world-wide, costs $250,000 for the entire system. The individual airframe itself is priced at only $35,000.[25] This difference in cost is often more pronounced with UAS operated by other countries. Even the relatively sophisticated Israeli Harpy sold to China at a per unit cost of only $500,000.[26] This number might seem high, but is demonstrably lower than the price of a modern military airframe conducting a similar mission. This reduced cost makes UAS more expendable than their manned counterparts influencing the level of risk acceptable to an unmanned airframe.

Perhaps the most significant benefit of removing the aircrew from the aircraft is the reduction of risk to the aircrew themselves. Ignoring any collateral damage, the loss of an unmanned system in combat or training can be equated to a monetary cost. For a manned system, the implications of a downed system are more severe. In addition to the loss of the aircraft, there is the obvious risk of injury, death, or capture to the pilot and the subsequent risk to resources tasked to conduct search-and-rescue. These considerations significantly affect decision-making regarding the employment of manned aircraft. Use of unmanned systems simplifies an adversary's calculation of risk considerably. With the human operator no longer in danger, much higher attrition rates become acceptable.[27]

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[24] Ashley Boyle, "The US and its UAVs: A Cost-Benefit Analysis," American Security Project, 24 July 2012, accessed 9 November 2015, http://www.americansecurityproject.org/the-us-and-its-uavs-a-cost-benefit-analysis/.

[25] sUAS News, "AeroVironment RQ-11 Raven," sUAS News, accessed 8 October 2015, http://www.suasnews.com/aerovironment-rq-11-raven/.

[26] Edward Cody, "China Scolds U.S. for Blocking Israeli Arms Sale," *Washington Post*, 28 June 2005, accessed 8 October 2015, http://www.washingtonpost.com/wp-dyn/content/article/2005/06/27/AR2005062700351.html.

[27] Lynn E. Davis et al., *Armed and Dangerous* (Santa Monica, CA: RAND Corporation, 2014), 11.

A short analysis of the relative advantages of unmanned aircraft over their manned counterparts shows how unmanned technology could potentially skew the current evaluation of risk posed by aerial threats. Increased persistence improves the effectiveness of the aircraft, particularly in a reconnaissance and surveillance role. Difficulty detecting and identifying a potentially smaller airframe diminishes the mitigation of risk provided by active air defense. Perhaps most significantly, low cost, expendability, and reduced risk to the crew make the use of unmanned systems far more acceptable even against a superior air power such as the United States.

Relative Disadvantages

As with the design of any system, every design choice features trade offs. One of the major advanatages of small UAS is their difficulty to detect. However, this advantage in turn limits payload. In the case of an attack UAS, larger munition requires a larger airframe which in turn increases radar cross section. Increased capability also comes with increase in cost, making the system less expendable. Many of the relative advantages of UAS appear significant, but are in fact self-limiting.

While removing the crew offers innovative benefits, it also places significant limitations on unmanned systems. The airframe still needs to be controlled somehow. In most cases this generates a dependency on datalinks for real-time communication both of control inputs to the vehicle as well as sensor outputs back to an operator on the ground. These datalinks present a greater vulnerability to electronic warfare than typically exists for manned aircraft. While a small unmanned airframe might be difficult to detect using radar, 'listening' for its electronic transmissions provides an alternative means of detection with other systems. UAS can be defeated through electronic warfare by removing means of control, or in the case of a surveillance platform, by jamming the sensor output the aircraft is tasked to provide.[28]

Some systems, particularly cruise missiles, mitigate this risk by flying without real time control. A set of preprogrammed waypoints are uploaded into the aircraft and it flies autonomously as directed. This eliminates some of the vulnerability of unmanned aircraft to electronic warfare, but it poses its own limitations. An UAS without real time communication conducting reconnaissance will not transmit images as they are taken. The intelligence gathered is not available until the UAS returns, limiting its usefulness. Additionally, an autonomous system, whether in a reconnaissance or attack role, cannot be retasked without reestablishing some form of datalink. The airframe must receive a transmission, endangering at least the ground control station, if not the aircraft itself.

Cruise missiles typically fly without real time control. Additionally, most land attack missiles lack an onboard capability to track mobile objects. As a result cruise missiles have difficulty hitting moving ground targets. Additionally, because UAS and cruise missiles lack the relative velocity and payload of most air-launched precision guided munitions, they are unable to reproduce the same degree of penetration against hardened targets.[29]

Summary

Unmanned aircraft and cruise missiles are capable of being employed in multiple roles. However, none of these roles are novel or new. The novelty of unmanned systems lies not in what they do, but how they do it. Removing the pilot and crew from the airframe offers significant advantages in persistence, detection, survivability, cost, and risk. These advantages come with a

[28] Jaysen A. Yochim, “The Vulnerabilities of Unmanned Aircraft System Common Data Links to Electronic Attack” (MMAS thesis, Command and General Staff College, 2010), 70-73.

[29] Mahnken, 35.

price, as UAS are heavily reliant on vulnerable datalinks and both UAS and cruise missiles have reduced capability against moving and hardened targets.

Chapter 2: Evaluating the Risk

To assess whether the US Army must adapt to proliferation of unmanned technology requires an evaluation of how the relative advantages and disadvantages described above affect the risk to the ground force and its mission. The methodlogy used to assess that risk is the familiar model provided by Army Techniques Publication (ATP) 5-19, *Risk Management*. Risk is a function of both probability and severity of a given hazard, in this case unmanned systems.[30]

Risk Assessment Matrix		**Probability** *(expected frequency)*				
		Frequent: Continuous, regular, or inevitable occurrences	**Likely:** Several or numerous occurrences	**Occasional:** Sporadic or intermittent occurrences	**Seldom:** Infrequent occurrences	**Unlikely:** Possible occurrences but improbable
Severity *(expected consequence)*		A	B	C	D	E
Catastrophic: *Mission failure, unit readiness eliminated; death, unacceptable loss or damage*	I	EH	EH	H	H	M
Critical: *Significantly degraded unit readiness or mission capability; severe injury, illness, loss or damage*	II	EH	H	H	M	L
Moderate: *Somewhat degraded unit readiness or mission capability; minor injury, illness, loss, or damage*	III	H	M	M	L	L
Negligible: *Little or no impact to unit readiness or mission capability; minimal injury, loss, or damage*	IV	M	L	L	L	L
Legend: **EH** - Extremely High Risk **H** - High Risk **M** - Medium Risk **L** - Low Risk						

Figure 1. Risk Assessment Matrix

Source: Army Techniques Publication (ATP) 5-19, *Risk Management* (Washington, DC: Government Printing Office, 2014), 1-7.

Discussion of probability focuses on proliferation and how likely the US Army will face an adversary that has developed or acquired these systems. Severity is assessed by the impact of unmanned systems to prohibit accomplishment of the US Army’s mission, particularly the

[30] Army Techniques Publication (ATP) 5-19, *Risk Management* (Washington, DC: Government Printing Office, 2014), 1–1 - 1–17.

relevant core competencies, outlined in Army Doctrine Publication (ADP) 3-0, *Unified Land Operations* and Training and Doctrine Command Pamplet (TP) 525-3-1, *The US Army Operating Concept: Win in a Complex World*: combined arms maneuver, wide area security, shape the security environment, set the theater, and project national power.[31]

Combined arms maneuver is the application of combat power to defeat an enemy, seize or defend terrain, and otherwise gain an advantage over an adversary. Wide area security is the application of combat power to protect populations, forces, and infrastructure and otherwise deny advantage to an enemy.[32] Shaping the security environment includes actions to reassure allies and deter adversaries, while setting conditions for potential operations. Setting the theater is the ability to establish and maintain vital infrastructure and lines of communication required for joint operations. Projecting national power is described as the ability to integrate other elements of national power and rapidly scale-up and sustain land forces through forward positioning of equipment and supplies.[33] While TP 525-3-1 lists additional competencies, these are the most relevant to air threats. It is against these competencies that severity will be assessed.

The analysis of relative advantages and disadvantages of unmanned systems and the impact to risk is then compared to two short case studies. The first is a contemporary study of a non-state actor, Hezbollah, and its employment of unmanned aircraft prior to, during, and after its 2006 conflict with a sophisticed conventional military opponent, Israel. The second case study is

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[31] Army Doctrine Publication (ADP) 3-0, *Unified Land Operations* (Washington, DC: Government Printing Office, 2011), 6; Training and Doctrine Command Pamphlet (TP) 525-3-1, *The U.S. Army Operating Concept: Win in a Complex World* (Washington, DC: Government Printing Office, 2014), 22-24.

[32] ADP 3-0, 6.

[33] TP 525-3-1, 22-24.

a counterfactual study of a near-peer conventional state actor, China, employing unmanned aircraft and cruise missiles in a simulated conflict with the US over the Taiwan Strait.

Unmanned Aircraft Systems

Probability

The likelihood of encountering adversary unmanned systems in future conflict is growing. Over seventy-five countries openly possess unmanned aircraft programs, and the number continues to grow.[34] Global investment in unmanned systems reached $6.6 billion in 2013, and a current assessment expects that number to nearly double over the following ten years. While the United States accounts for a large proportion of current UAS expenditures, the increased spending anticipated in the near future is almost entirely due to investment by other countries.[35]

Proliferation of UAS is certainly not limited to state actors. Terrorist, paramilitary, and criminal organizations have all demonstrated the ability to acquire unmanned systems, either through state benefactor or through modification of commercially available remote control aircraft. During the 2006 conflict between Israel and Lebanon, Hezbollah employed Iranian systems developed for military use.[36] Alternatively, the Revolutionary Armed Forces of Columbia modified several civilian model airplanes to carry an explosive charge for use in a terror role.[37]

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[34] US Government Accountability Office, “Key Issues: Unmanned Aerial Systems (Drones),” GAO, accessed 3 November 2015, http://www.gao.gov/key_issues/unmanned_aerial_systems/issue_summary#t=0.

[35] Davis et al., 7-10.

[36] Lambeth, 130-133.

[37] Jackson et al., 11-14.

The dual-use nature of UAS and the availability of enabling technology make limiting proliferation to both state and non-state actors difficult. Airframes designed for recreation or commercial use are readily accessible. Complementary technologies are also increasingly available for low costs. Inexpensive and lightweight navigation, communication, and surveillance equipment enhance the proliferation of capable unmanned systems.[38]

With the large number of current operators, expanding investment, and difficulty in limiting proliferation, the probability of encountering adversary UAS in future combat is likely. Global proliferation and availability to state and non-state actors alike makes adversarial UAS a possibility regardless of the location and nature of the next conflict. However, while UAS programs might exist in several countries, the capabilities of individual unmanned systems vary widely. Probability alone does not constitute the danger UAS pose to the US ground forces. An evaluation of the severity of the threat posed by UAS is required to assess the overall risk.

Severity

The severity of the threat posed by UAS to combined arms maneuver appears to be self-limiting. While the expendibility of attack UAS makes employment acceptable to an adversary despite US Air Force dominance, the contradiction between payload size and difficult detection either limits the likelihood of reaching its target undefeated, or the size of munition it will have to employ. Adversary UAS employed in a surveillance role also have the ability to complement the effect of other assets such as indirect fires. The severity of the UAS hazard in such a role varies widely as it depends largely on the existing capability being supported. While a UAS might be able to degrade a ground unit's ability to accomplish its mission, it is unlikely by its own merits alone to significantly degrade a ground force to such an extent that its mission was in jeopardy.

[38] Davis et al., 2.

The severity of the direct UAS hazard to wide area security is likewise limited by the contradiction between payload and detection. Perhaps more significant than the physical danger is the psychological effect of the threat to rear areas that would otherwise be considered comparably safe. UAS are not sufficient by themselves to destroy the infrastructure necessary to set the theater and project national power, but can still degrade the Army's ability to perform its mission, especially when combined with other capabilities. UAS pose a moderately severe risk to these other core competencies. Considering both probability and severity if the UAS threat, unmanned technology elevates a previously insignificant risk of air attack to a medium risk.

Cruise Missile Risk

Probability

The probability of encountering a adversary capable and willing to employ cruise missiles against US ground forces is not as high as unmanned aircraft, but the likelihood is growing. While almost seventy countries possess cruise missiles systems, the majority are anti-ship cruise missiles, limited to maritime targets. Only sixteen countries have known indigenous land attack cruise missile (LACM) programs, six of which are members of mutual defense alliances involving the United States. However, multiple avenues are available for other countries to gain a similar capability through import, modification of existing anti-ship cruise missiles, or converting unmanned aircraft.[39]

Import of cruise missiles is more difficult than UAS. Of the countries with known indigenous LACM programs, nine are member of the Missile Technology Control Regime

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[39] Mahnken, 19-30; Dennis M. Gormley, "Winning on Ballistic Missiles, but Losing on Cruise: The Missile Proliferation Battle," Arms Control Association, 4 December 2009, accessed 15 December 2015, https://www.armscontrol.org/act/2009_12/Gormley.

(MTCR).[40] Another two, China and Israel, have either applied for membership or have announced adopting the regime guidelines unilaterally.[41] The MTCR is not a comprehensive ban on exporting missile technology, but is a voluntary restraint on technologies that directly or indirectly provide the capability to deliver a 500 kilogram payload 300 kilometers. MTCR is designed specifically to limit rockets, missiles or drones capable of carrying WMD, and less capable systems are not included in its restrictions.[42]

The threshold contained in the MTCR provides for loopholes. Payload and range are not independent specifications; reducing payload increases maximum range. By fudging these numbers, multiple MTCR members have skirted the prohibition on technologies. The United Arab Emirates purchased Apache missiles from France. The United Kingdom and Russia have both sold missiles to China and India.[43] As a voluntary agreement, the MTCR lacks a means of enforcement for violations other than actions taken by individual members.[44]

The MTCR agreement limits missile technology export from the known producers of land attack cruise missiles, but the possibility exists for LACM programs to exist outside those countries. Due to the similarity in required technologies, LACM development can easily be hidden within aircraft production. The US intelligence community has missed several advances in cruise missile technology, such as Pakistan's Babur missile, revealed during a surprise demonstration in 2005.[45]

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[40] "The Missile Technology Control Regime," Missile Technology Control Regime, accessed 15 December 2015, http://www.mtcr.info/english/partners.html.

[41] "The Missile Technology Control Regime at a Glance," Arms Control Association, last modified 6 November 2015, accessed 14 December 2015, http://www.armscontrol.org/factsheets/mtcr.

[42] Ibid.

[43] Gormley, *Missile Contagion*, 55-62.

[44] "The Missile Technology Control Regime at a Glance."

[45] Gormley, *Missile Contagion*, 55-65.

What were once difficult technological hurdles required to convert anti-ship cruise missiles to a land attack role are now easily overcome. Previously, one of the biggest obstacles to development of a LACM was the required guidance system. To fly at low altitude over terrain required sophisticated guidance systems such as high accuracy inertial navigation and Terrain Countour Matching. With precise navigation and timing provided by Global Positioning Service (GPS), or the Russian and Chinese equivalents of Global Navigation Satellite System and Bei Dou, previous sophisticated guidance systems are no longer required. An anti-ship cruise missile or UAS carrying a warhead and proper navigation equipment could perform a land attack role. The technological barriers to developing land attack cruise missiles have greatly diminished.[46]

Unless in a direct conflict with Russia, China, or any of the other known producers or purchasers of LACM, the probability of facing a cruise missile threat is unlikely. However, it is not absent. The United States has already demonstrated an inability to conclusively assess the proliferation of cruise missiles either through direct export, local development or conversion from existing systems.

Severity

The severity of the cruise missile hazard to combined arms maneuver is only moderate. Cruise missiles typically lack real time control and terminal guidance is either based on terrain matching or GPS coordinates. As such, they are suited for strikes on stationary targets, not a mauevering tactical force.[47] The more significant risk posed by cruise missiles is to wide area security. Given a high level of accuracy against stationary targets, heavy payload, difficulty to

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[46] Mahnken, 20-21, 28-30.

[47] Ibid., 32-35.

defeat by active air defenses, and reduced risk to employment, cruise missiles are capable of destroying mission essential forces or infrastructure even in rear areas, inducing mission failure.

As a key enabler for A2AD, the hazard posed to mission critical infrastructure in rear areas extends to air bases and seaports serving as points of disembarkation for forces to enter the theater.[48] Even if these assets can be recovered, they would remain vulnerable if the cruise missile launcher is not eliminated, a difficult task given their range and survivability. The ability for an adversary to strike these vital assets negatively affects the Army's ability to set the theater and project national power abroad. If left unmitigated, the severity of a successful cruise missile attack to these core competencies can be catastrophic to the US Army mission.[49]

Overall Risk

The probability of facing adversary unmanned systems is likely and their relative advantages over other airframes elevate risk to the US Army and its mission. The expendable nature of unmanned technology alters the threshold of acceptable risk in employment of air threats against US ground forces. Difficulty detecting these threats improves their chances of success. However, the severity of attack by UAS is limited by small payload, which if increased would then offset relative advantages in expendability and detection. The specific case of attack by sophisticated LACM is unlikely depending on the adversary, but the severity of the threat is potentially catastrophic. The proliferation of both UAS and cruise missiles appears to elevate the threat of air attack from insignificant to at least a medium risk to Army forces and their mission.

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[48] Gordon and Matsumura, 5-8, 12-14.

[49] Christopher J. Bowie, *The Anti-Access Threat and Theater Air Bases* (Washington, DC: Center for Strategic and Budgetary Assessments, 2002), iii-iv, 40-49.

Case Study #1 Hezbollah UAS

In 2006, the Israeli Defense Force (IDF) attacked into southern Lebenon, with a goal to recover two kidnapped Israeli soldiers and degrade Hezbollah as an effective fighting force. The two sides of the conflict were certainly not playing on a level field. The IDF was a far more sophisticated military, with a dominant conventional air force and integrated air defense system. The Israeli Air Force averaged 340 sorties per day. Conversely, Hezbollah did not field a single manned aircraft. And yet, Hezbollah still attempted to attack Israel though the air.

During the 2006 conflict, Hezbollah launched three UAS with the intention of striking targets inside Israel. This tactic had been validated earlier in April 2005, when Hezbollah flew an unmanned aircraft over settlements in northern Israel for nearly ten minutes unopposed, then successfully returned to Lebonese airspace. Due to the relative advantage of reduced radar cross section the unmanned aircraft initially went undetected by Israeli sensors.[50] In 2005 the UAS carried a camera; in 2006 the UAS carried explosives.[51] However, the planned attack did not succeed. Of the three UAS employed by Hezbollah in 2006, one crashed while still in Lebonese airspace. The other two were downed by Israeli aircraft flying combat air patrols in case of just such an attack. One crashed off the coast of Israel near Haifa to be recovered later by the Israeli navy, the other crashed overland just across the border.[52]

Athough attacks by the three UAS in 2006 were unsuccessful, this does not mean they were insignificant. Without unmanned technology, attack by air was not even feasible for

[50] "Hezbollah Mirssad-1 UAV Penetrates Israeli Air Defenses," Defense Industry Daily, LLC., 20 April 2005, accessed 3 December 2015, http://www.defenseindustrydaily.com/hezbollah-mirsad1-uav-penetrates-israeli-air-defenses-0386/ accessed 3 December, 2015.

[51] Anthony H. Cordesman, George Sullivan, and William D. Sullivan, *Lessons of the 2006 Israeli-Hezbollah War* (Washington DC: Center for Strategic and International Studies, 2007), 105-107.

[52] Lambeth, 130-133.

Hezbollah. The probability of air attack by Hezbollah manned aircraft was nil, and even if they possessed manned aircraft they would have been doomed to defeat by the superior Israeli Defense Force and its integrated air defense. The simple fact that the attack was attempted shows unmanned technology increased the probability of enemy action in the air, either as reconnaissance or in a direct attack role. This increased probability is a reflection of the ease of UAS proliferation as Hezbollah is heavily subsidized by Iran, and the UAS employed in each attempt were of Iranian design.[53]

This particular example does not demonstrate an increase to the severity of risk posed by unmanned systems. None of the attack UAS reached their intended target. Even if they had, the UAS employed at most could carry forty kilograms of explosives; the one recovered by the Israeli navy carried only ten. These payload sizes were on the same order of magnitude as the warhead in a single Kyatusha rocket, which Hezbollah fired by the thousands during the conflict.[54] The severity of UAS attack in this case was negligible compared to other capabilities.

The effect of unmanned reconnaissance to the severity of adversary UAS is more difficult to measure as there is a lack of evidence indicating Hezbollah used UAS surveillance to support maneuver or indirect fires. The severity of surveillance is negligible in this case, but potentially could have been greater. With approximately 4,000 rockets fired into Israel, Hezbollah killed only forty-three Israelis.[55]An Ababil can carry a similar payload to a single Kyatusha rocket in a direct

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[53] Lambeth, 132.

[54] Cordesman, Sullivan, and Sullivan, 105-107.

[55] Yochi Dreazen, "The Next Arab-Israeli War Will Be Fought with Drones," *New Republic,* 26 March 2014, accessed 15 March 2016, newrepublic.com/article/117087/next-arab-israeli-war-will-be-fought-drones.

attack, but that same aircraft could also locate targets or adjust fire for thousands of Kyatusha rockets to improve their effectiveness, a technique validated in multiple US Army exercises.[56]

Just because the three UAS attacks in 2006 failed, does not mean the threat can be safely ignored. Six years later in October, 2012, Hezbollah flew an Iranian UAS into Israeli airspace roughly 145 miles into southern Israel near Dimona, potentially transmitting imagery of a sensitive Israeli nuclear facility before being destroyed by the IDF.[57] In 2014, Hezbollah successfully employed attack UAS against Al-Nusra fighters in the Syrian Civil War.[58] The advantage of an armed Ababil over the Kyatusha rocket is the Ababil can be flown precisely at a point target such as a prepared fighting position or specific infrastructure like that at Dimona. Again, the 2006 use of UAS by Hezbollah does not demonstrate an increase in severity of the UAS hazard, but later successes do not refute the possibility.

The example of Hezbollah's employment of UAS against Israel fails to demonstrate a clear increase in the severity of aerial threats due to unmanned technololgy. It does however provide evidence that the probability of adversary action through the air is increased regardless of the sophistication of the opposing integrated air defense system. If limited to just manned aircraft, challenging Israeli air superiority would not have been a viable option. However, unmanned aircraft provided Hezbollah a means to operate against the IDF in both a surveillance and direct

[56] Shannon D. Judnic and Micahel J. Burke, "Electronic Fires," *Fires* (March-April, 2014): 16-17, accessed 7 November 2015, http://sill-www.army.mil/firesbulletin/2014/mar-apr/mar-apr.pdf.

[57] Milton Hoenig, "Hezbollah and the Use of Drones as Weapon of Terrorism," *Public Interest Report* 67, no. 2 (Spring 2014), accessed 3 December 2015, http://fas.org/pir-pubs/hezbollah-use-drones-weapon-terrorism/.

[58] Adiv Sterman, "Hezbollah Drones Wreak Havoc on Syrian Rebel Bases,"*Times of Israel*, 21 September 2014, accessed 26 February 2016, http://www.timesofisrael.com/hezbollah-drones-wreak-havoc-on-syrian-rebel-bases/.

attack role. Hezbollah achieved at best only a few marginal successes, but no more than two UAS were ever launched at the same time. What if an adversary were able to employ many more?

Case Study #2 RAND Taiwan Strait Simulation

The People's Republic of China is actively pursuing unmanned systems, particularly long range reconnaissance and strike platforms to project power over the Pacific. According to a Defense Department report to Congress, China intends to invest $10.5 billion to expand its UAS program to over 40,000 unmanned systems by 2023.[59] This is in addition to an existing inventory of several hundred LACM capable of reaching US bases in Japan, Guam, and Hawai'i.[60]

In 2009, the RAND Corporation conducted a simulation of a conflict between the People's Republic of China and the United States over the Taiwan Strait based on projected capability in 2015. This study primarily regarded the air war and the ability of China to counter the US air component. With UAS and cruise missiles used against ground targets there is potential for insight into how proliferation of these systems could be used to interfere with the land component and its mission in a future conflict. As a simulation, the results of the study reflect only a best guess as to how the Chinese would employ these systems in support of an invasion of Taiwan and an estimation of their effectiveness in such a role.

In the scenario simulated by RAND, China launched a sophisticated strike against critical infrastructure in Taiwan, and also against US bases in the Pacific. Combining manned and unmanned aircraft with ballistic and cruise missiles, China sought to obtain an immediate advantage through structured attack in which unmanned systems played a significant part. Short

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[59] Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015,* April 2015, 9, 34-47.

[60] Jeffrey Lin and P.W. Singer, "China Shows Off Its Deadliest New Cruise Missiles: DH-10 for a Speedy 1100-Pound Delivery," *Popular Science*, 10 March 2015, accessed 11 December 2015, http://www.popsci.com/china-shows-its-deadly-new-cruise-missiles.

range ballistic missiles were initially used to sever runways in both Okinawa and Taiwan, limiting sortie generation. This initial volley was paired with strikes by Harpy anti-radiation drones to destroy radar sites required for Taiwan's high altitude surface-to-air missiles. Suppressing both airborne and ground-based active air defense, China eliminated prohibitive interference to its air component. As a result, Taiwan was left vulnerable to subsequent strikes on aircraft and aircraft hangers by a combination of cruise missiles and manned aircraft, cementing a condition of Chinese air superiority during a subsequent amphibious invasion.[61]

Should hostilities commence between the People's Republic of China and the United States over Taiwan, the probability of UAS and LACM employment is very high. This is not just evidenced by the results of the 2009 RAND simulation, but by trends in research, development and acquisitions.[62] Chinese doctrine includes the use of anti-radiation UAS and cruise missiles to suppress enemy air defenses. Cruise missles, in conjunction with ballistic missiles are the primary means of striking air bases and other deep targets.[63]

The RAND simulation seemingly indicates a Chinese attack against US bases in the Pacific would have a severe impact on the mission of the United States. However, this conclusion does not clearly indicate the contribution of unmanned systems alone. China may well have succeeded in the scenario with only its inventory of surface-to-air missiles, ballistic missiles, and manned aircraft. To gauge severity, the specific capability allowed by UAS and cruise missiles must be separated from these other platforms and evaluated by their individual contribution. In the simulation anti-radiation platforms were used to successfully suppress Taiwanese and US

[61] David A. Shlapak et al., *A Question of Balance: Political Context and Mlitary Aspects of the China-Taiwan Dispute* (Santa Monica, CA: RAND Corporation, 2009), 53-62.

[62] Office of the Secretary of Defense, 9, 34-47.

[63] Roger Cliff et al., *Shaking the Heavens and Splitting the Earth: Chinese Air Force Employment Concepts in the 21st Century* (Santa Monica, CA: RAND Corporation, 2011), 59-60, 97-113, 130-137, 188-223.

ground-based air defense, demonstrating a severe risk to the Army's ability to conduct wide area security of critical assets. Cruise missiles were subsequently used to disrupt and degrade distant bases. Although the RAND study examines the effect on the US Air Force, the implications for the Army are easily translated. Outside of a Taiwan scenario, the targeted airbases in the Pacific could just as easily have been distant points of disembarkation for ground forces to enter a theater in Europe or the Middle East. The success of the overwhelming Chinese attack demonstrates an ability for UAS and cruise missiles to severely challenge the Army's ability to set the theater and project national power.

Summary

The emergence of unmanned technology supports an increase in risk from the air that is no longer negligible. While the historical example of Hezbollah employing unmanned technology demonstrates an increased probability of facing interference from the air, the counterfactual case study provided by the RAND simulation shows the severity of such an attack when conducted in greater numbers structured with other air and missile threats. The Hezbollah attacks were few in number and mostly unsuccessful, but still support an increase in probability of air attack. The Taiwan Strait scenario is based on a simulation and all the assumptions that went into that model potentially distort the results, but the severity of adversary action through the air is potentially catastrophic. Neither case definitively demonstrates the precise risk of unmanned technology to the US Army mission in future conflict, but both cases demonstrate a significant increase in overall risk if not mitigated.

Chapter 3: Mitigation

The proliferation of unmanned technology challenges the assumption that ground forces will operate under air superiority. The United States has enjoyed air superiority for decades, and recent conflicts in which US air superiority were challenged are few.[64] To determine possible mitigations, this chapter examines the accumulation of lessons learned operating under an air threat in the European Theater during World War Two. The following case study focuses on the defense of the Remagen Bridgehead in 1945, an example of an adversary challenging local air superiority in an attempt to defeat ground forces. At Remagen, Army forces incorporated lessons in air defense from previous campaigns in North Africa and Italy. However, the means employed by the Luftwaffe in 1945 at Remagen are not the same as contemporary threats. The mitigations employed in 1945 are evaluated based on the relative advantages and disadvantages of unmanned systems to determine if they are still valid, require modification, or should be rejected. These resulting requirements are then contrasted with current US capability to determine if possible mitigations exist to improve performance under the emerging unmanned threat.

Case Study #3: Defense of the Remagen Bridgehead

In March 1945, elements of the Ninth Armored Division met with unanticipated success while driving toward the Rhine River. Elements of the division at Remagen captured the Ludendorff Bridge intact, the demolitions set in place by the Germans having only partially detonated. By the afternoon of 7 March, 1945, the damaged but still standing bridge was in Allied hands. Although not a planned crossing site, the Ludendorff Bridge gave the US Army an opportunity to cross the last major barrier to Germany and deny the Wehrmacht the opportunity to mount a defense along the river. Understanding the gravity of the bridge capture, German

[64] Randy Roughton, "Air Superiority: 60 Years in the Making," *Air Force News Service*, 23 April 2013, accessed 8 October 2015, http://airforcelive.dodlive.mil/2013/04/air-superiority-60-years-in-the-making/.

soldiers counterattacked that evening. Delayed by poor communications, the counterattack lacked sufficient ground forces to dislodge the growing American bridgehead east of the Rhine.[65]

After the failure of the initial counterattack by ground, the Germans attempted to destroy the damaged bridge by air. By 1945, the Luftwaffe was seriously attrited and the Allies had achieved a general level of air superiority. The risk to German pilots and aircraft was high, but the significance of the bridge capture altered the threshold of acceptable risk. Despite Allied command of the air, the Luftwaffe still possessed sufficient resources and motivation to challenge local air superiority at the bridgehead.[66]

Allied anti-aircraft artillery (AAA) raced to Remagen. 482nd AAA, organic to Ninth Armored Division advanced through the division column to emplace at the bridge. With the vulnerability of the congested forces pushing across the bridge, the division called for additional active air defense echeloned at III Corps and First Army. Connected by wire communications, other AAA elements in First Army were already aware of the bridge capture the night of the seventh. AAA concentrated upon Remagen over the next three days growing from one battalion to seven by 10 March and even more by the following week.[67]

The Luftwaffe did not wait for AAA to finish massing at Remagen, counterattacking the day after the bridge capture with three Stuka dive-bombers and one Bf109 fighter. The reappraisal of risk was evidenced by the German pilots. The risk of the bridgehead outweighed the risk to aircraft and pilot and the Luftwaffe planes refrained from evasive maneuvering in order to improve the accuracy of their attack. All four were shot down by anti-aircraft fire, but

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[65] Drew Rawson, *Remagen Bridge* (South Yorkshire, UK: Pen & Sword Books, 2004), 55-116.

[66] Paul Semmens, "The Hammer of Hell: The Coming of Age of Antiaircraft Artillery in WWII," *ADA Magazine,* accessed 18 August 2015. http://www.skylighters.org/hammer/.

[67] Ibid.

one Stuka successfully hit the approach to the bridge doing minor damage repaired by engineers in fifteen minutes.[68] Shortly thereafter another eight Stuka dive-bombers attacked in similar fashion and were similarly destroyed, this time without any success.[69]

On the evening of 8 March, Supreme Headquarters Allied Expeditionary Force declared the area surrounding Remagen an Inner Artillery Zone. Allied aircraft were prohibited from the area and the defense of the bridgehead fell entirely on AAA elements now authorized to engage unknown targets without establishing identification. This declaration was planned in advance for any potential river crossing in order to allow AAA to defend the bridge at night when identification was impossible and prevent the fratricide of friendly aircraft that was so prevalent in earlier campaigns.[70] Two more aircraft attacked that evening under cover of darkness, but were engaged by AAA and aborted their approach before attacking the bridge.[71]

With the Army Air Corps now excluded from a fifteen kilometer radius around the bridge, supporting US pilots pushed deeper into Germany to support the bridgehead. The Ninth Air Force destroyed nearby rail lines and interdicted German reinforcements in order to isolate the bridgehead from German counterattacks on the ground. In addition, US pilots conducting offensive counterair targeted multiple nearby airfields east of Remagen to reduce German sortie generation against the bridgehead.[72]

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[68] Headquarters, European Theater of Operations, *Anti Aircraft Artillery Notes*, No. 24, 4 April 1945, 2-6.

[69] Ibid.

[70] Semmens; Kenneth P. Werrell, *Archie, Flak, AAA, and SAM: A Short Operational History of Ground-Based Air Defense* (Maxwell AFB, AL: Air University Press, 1988), 46-51.

[71] Headquarters, European Theater of Operations, *Anti Aircraft Artillery Notes*, No. 22, 21 March 1945, 3.

[72] Eric Hammel, *Air War Europa: America’s Air War Against Germany in Europe and North Africa* (Pacifica, CA: Pacifica Press, 1994), 455-460.

In the days that followed the bridge capture, the Luftwaffe employed several of its more innovative systems against the Remagen lodgment. Attacks by ME262 and AR234 jet aircraft began on 9 March and Germans fired eleven V-2 rockets at the bridge.[73] Both the jet aircraft and the V-2 rockets allowed little to no warning of attack. Though one rocket did kill three American soldiers, the V-2 was far too inaccurate to produce any appreciable effect on the bridge.[74] The jets, however, were more dangerous and especially difficult to defeat compared to propeller aircraft. With quieter engines and flying at much higher speeds, these threats allowed significantly less warning and less reaction time to counter. Attacks by jet aircraft peaked on 14 March, with sixty-seven jets of ninety-two attackers. Only eight aircraft were confirmed destroyed. Of the several German aircraft shot down at Remagen, proportionately few were jet aircraft.[75]

Implementation of barrage fire reduced the effectiveness of German jet aircraft, particularly during night attacks, by denying airspace to the attacker. Barrage firing did not prevent German jet aircraft from attacking, but the high rate of speed and maneuvering that allowed the jet to penetrate the barrage also reduced the accuracy of the bombing. Barrage fire came at an increased cost in ammunition, but prevented German pilots from scoring a direct hit on the bridge.[76]

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[73] Ken Hechler, *The Bridge at Remagen* (New York, NY: Ballantine Books, 1957), 186-192.

[74] D.D. Science, V.2. Attacks on Bridges, memorandum, 19 March 1945, accessed 6 December 2015, http://www.v2rocket.com/start/deployment/remagen_probabilities.jpg.

[75] Headquarters, European Theater of Operations, *Anti Aircraft Artillery Notes*, No. 24, 4 April, 1945, 2-6.

[76] Ibid., 6. 3,226 90mm shells, 54,680 40 mm shells, 9,426 37mm shells, and 1,641,059 .50 caliber rounds were expended from 8 March through 22 March at Remagen alone.

On 17 March, 1945, the Ludendorff Bridge finally collapsed. By that time it was no longer necessary. The bridgehead was established and by 13 March most traffic had already shifted to three ferries and two tactical bridges constructed by engineer elements under First Army.[77] The Luftwaffe had committed 433 sorties to the Remagen bridgehead, with AAA claiming 126 of those aircraft destroyed and another forty-six probably destroyed. The Luftwaffe challenged local Allied air superiority in an attempt to prohibit the crossing of the Rhine at Remagen and failed, not because of Allied airpower but because of the capabilities of the American ground force to operate under such a challenge.

Analysis

The defense of the Remagen bridgehead is a dramatic example of a ground force operating under a challenge to local air superiority. Multiple capabilities contributed to American success in securing and expanding the bridgehead despite repeated attacks from the air by the German Luftwaffe. However, the character of the challenge to air superiority posed by German aircraft and rockets in 1945 is not necessarily the same as that posed by unmanned systems today. The mitigations learned prior to and during the defense of the bridgehead do not necessarily translate. This section seeks to identify the lessons learned prior to and during Remagen that allowed the Americans to be successful and determine if those lessons remain valid, require further modification, or should be discarded, based on the relative advantages, disadvantages and risk previously identified.

There are three overarching lessons demonstrated at Remagen that allowed the US Army to successfully operate under the threat of air attack. First, active air defense was organized in a fashion that both allowed immediate defense by Ninth Armored Division's organic AAA against

[77] Office of the Engineer, First United States Army, *Report of Rhine River Crossings*, May 1945, 1-7.

the initial Luftwaffe attacks and allowed concentration of AAA against subsequent attacks. Second, passive measures were in place to reduce or repair the impact of a successful strike on the bridge. Finally, the use of airspace deconfliction and air interdiction shaped conditions that allowed AAA units to operate freely while reducing the Luftwaffe's offensive capability.

Active Air Defense

The first key to the initial defense of the bridgehead was the ability for active air defense to mass at critical points as they emerged. One of the great weaknesses of the defense is it cedes the initiative to the attacker.[78] This limitation applies equally to defense against attacks from the ground and attacks from the air. The defender is fixed to the assets being defended, with the attacker free to concentrate forces at a time and place of their choosing. Perhaps counterintuitively, the defender must be mobile in order to react and shift the defense appropriately once the attacker reveals his plan. A scarce asset, active air defense needed to be able to mass rapidly at critical points on the battlefield in order to be effective. At Remagen, the location and timing of the impending Luftwaffe attack was clearly revealed. Within seventy-two hours of the bridge capture, AAA assets under First Army massed at the decisive point through inherent mobility and an organizational structure that supported their concentration.

One of the major debates regarding AAA in the European theater prior to Remagen was the organization of air defense within the larger formations: should AAA be organic to maneuver units or pooled at a higher level to issue down as needed?[79] At the outset of operations in North Africa, the US Army pooled active air defense centrally in AAA brigades separate from divisions and corps. US planners anticipated the Luftwaffe would operate similar to their own US Army

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[78] Antoine Jomini, "Summary of the Art of War," in *Roots of Strategy*, ed. And trans. Brig. Gen. J.D. Hittle (Harrisburg, PA: Stackpole Books, 1987), 462-464, 494-498.

[79] Semmens.

Air Corps, focused primarily on strategic bombing rather than tactical close air support. German air attacks were anticipated against critical infrastructure in rear areas and echeloning AAA above corps made sense to defend strategic assets. However, German tactics in North Africa invalidated this assumption and pooled AAA proved too slow in response to German close air support. By Remagen, US commanders settled the debate in a compromise. AAA automatic weapons battalions were organic to each division, and a further AAA group assigned to each corps.[80]

This structure allowed immediate defense to the lead maneuver units while still allowing flexibility for the corps commander to defend rear areas or mass additional defensive capability where needed.[81] 482nd Automatic Weapons Battalion, 9th Armored Division's organic active air defense, conducted the initial defense of the bridgehead. The ensuing concentration of AAA was provided by the 16th AAA Group from III Corps and later the two AAA battalions from Ninth's sister divisions, the 9th Infantry and 78th Infantry.[82] This structure helped offset the difficulty of detecting air threats. Early warning for maneuver units in 1945 was still very primitive. Difficulty providing early warning for front line forces necessitated the flexible force structure of AAA at Remagen. Divisional air defense had to be with the maneuver units because air attack could occur at any time with little warning. AAA units assigned to the Ninth Armored Division were on hand to secure the vulnerable bridge and subsequent bridgehead from the initial Luftwaffe attacks. Additional AAA massed from elsewhere, but obviously could not react as quickly by ground as the Luftwaffe could by air.

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[80] Bryon E. Greenwald, "Understanding Change: An Intellectual and Practical Study of Military Innovation; U.S. Army Antiaircraft Artillery and the Battle for Legitimacy, 1917-1945" (PhD diss., The Ohio State, 2003), 332-338, 381-384, accessed 12 November 2015, http://rave.ohiolink.edu/etdc/view?acc_num=osu1070502037.

[81] Ibid.

[82] Semmens.

The need for flexible structure driven by the Luftwaffe in World War Two appears applicable to the modern threat posed by unmanned systems. As already stated, one of the relative advantages of UAS and cruise missiles is their difficulty to detect and identify. With reduced early warning, active air defense must already locate with maneuver units if they are to provide immediate protection. However, unmanned systems threaten more than forward maneuver units. They can also penetrate into rear areas, as demonstrated by Hezbollah's UAS flight to Dimona, or mass effects at specific critical assets, as demonstrated in the Taiwan Strait simulation against US bases. The US Army in the European theater ultimately solved this problem by balancing both organic defense at the division with echeloned AAA at the corps that could defend rear areas and concentrate at critical points such as Remagen. This requirement for balance in organization validated at Remagen is applicable today. To mitigate the relative unmanned advantages in difficulty of detection, reduced risk, and low cost, the US Army requires organization that provides immediate protection to both maneuver units and rear areas with little warning while retaining the ability to concentrate when needed against an overwhelming attack.

However, the capability to provide organic air defense is no longer present in the active component.[83] Organic air defense has been removed from US Army divisions, and maneuver air defense capability now exists only in the National Guard.[84] The high-altitude systems that remain require heavy vehicles to transport and time to emplace before being ready to fire from a new location. They are not as mobile as the maneuver units they would potentially protect. For

[83] John A. Hamilton, *Blazing Skies* (Washington DC: Government Printing Office, 2009), 293-302, 314-317; "32nd AAMDC," US Army, accessed 14 December 2015, https://www.bliss.army.mil/32nd/.

[84] Gary Sheftick, "Short-Range Air Defense Back in Demand," US Army, 12 February 2016, accessed 22 February 2016, http://www.army.mil/article/162389.

example, Patriot batteries, designed for linear Cold War battlefields, struggled to keep pace with supported maneuver forces moving cross-country during Operation Iraqi Freedom.[85]

This lesson, the need for an organizational structure that allows immediate active defense balanced with an ability to mass at critical areas of the battlefield, has been forgotten. Decades spent enforcing no-fly zones and defending fixed sites from ballistic missiles has invalidated this requirement in the years since World War Two. The proliferation of unmanned systems, and the increased risk to air superiority they represent, bring back this overlooked lesson.

Passive Defense

Active air defense is not the only means to reduce risk from air attack. The defense of the Remagen bridgehead shows the value of passive countermeasures as well. The engineers at Remagen played a crucial role in preserving and expanding the bridgehead. While AAA prevented any direct hits on the bridge, on the first day a near miss damaged the approach to the bridge. Repairing this marginal success from the German attack took only a matter of minutes. After 13 March, even a direct hit destroying the bridge would not have been catastrophic as most traffic had shifted to redundant ferries and tactical bridges erected along the river nearby. Redundancy and repair significantly mitigated the Luftwaffe threat. If AAA was unable to defeat the attack, a successful strike on the bridge might not have prohibitively interfered with the First Army crossing because of passive mitigation provided by the engineers.[86]

The relative advantages and disadvantages of unmanned aircraft and cruise missiles magnify this lesson regarding the importance of passive defenses under such a threat. Challenges

[85] 32nd Army Air Missile Defense Command, "Theater Air and Missile Defense Implications of Operations Iraqi Freedom and Enduring Freedom," *Air Defense Artillery*, (April-June 2005): 7-9, accessed 26 February 2016, http://sill-www.army.mil/ada-online/pb-44/_docs/2005/4-6/ADA_MAG%20April-June%202005.pdf.

[86] Office of the Engineer, 10, 36-42.

in detection and identification of unmanned systems translate into greater difficulty defeating these threats with active defenses. However, the difficulty of unmanned systems striking moving targets or penetrating hardened shelters translates into greater levels of mitigation with passive defenses. Hezbollah conducted its successful strike against al-Nusra on unarmored personnel in the open. It is unlikely a similar strike would produce the same risk to force against soldiers dug in under concealment.

Passive air defense is equally significant protecting the US Army mission. The RAND simulation shows both unmanned aircraft and cruise missiles play a critical role in denying US access to the Taiwan theater. The Luftwaffe counterattack at Remagen was itself a form of A2AD responding to the US Army forcibly crossing the last defensible barrier on the German frontier. The Germans committed so many scarce resources to the bridgehead because of the considerable advantage the lodgment offered to the Allies. Similarly, the simulated Chinese attacks in the RAND study intended to not only overwhelm Taiwan, but to prevent US forces from entering the theater.[87] In both cases the air threat targeted US ability to secure a wide area and set the theater, tasks for which UAS and cruise missiles are well suited.[88]

Passive air defense is not only a matter of cover and concealment, but also of planning. Remagen was not the site originally planned for the Allied Rhine River crossing. Multiple points had previously been identified along the Rhine north of the Ruhr, and another to the south near Frankfurt.[89] These planned sites were both dispersed and redundant, preventing a concentrated German attack from disrupting both crossings and allowing Allied forces to continue to cross

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[87] Shlapak et al., 53-62.

[88] Gordon and Matsumura, 12-14.

[89] Charles B. MacDonald, *United States Army in World War II: The European Theater of Operations; The Last Offensive* (Washington, DC: Center of Military History, 1984), 208-209.

even if the Germans successfully denied one. These two operational methods of passive air defense were valid in World War Two and are still valid today against modern air threats. In the Taiwan Strait simulation, RAND identified dispersion and redundancy of US aircraft basing as possible mitigations.[90] However, scarce availability of active defenses can constrain dispersion if the dispersed assets still remain within range of a credible threat.[91]

Both the Hezbollah and Taiwan Strait cases highlight a third form of operational passive defense in dislocation – placing critical infrastructure beyond an enemy's reach. Although the Hezbollah aircraft downed near Dimona penetrated deeply into Israeli airspace, the distance travelled still allowed additional time for Israel to detect and defeat the threat. Similarly, in the Taiwan Strait simulation, RAND concluded that placing US forces beyond the range of China would prevent unmanned aircraft and cruise missiles from threatening US bases, albeit with a negative impact to operational reach and logistics.[92] Just as dispersion needs to be balanced with the availability of active defense, dislocation needs to be balanced with the negative impact to the length of lines of communication.[93]

Despite the recent lack of an immediate air threat to the US Army, residual passive air defense capability remains within the US Army at the tactical level with armored vehicles, radar-scattering camouflage, and engineering assets to protect, conceal, and repair friendly forces and infrastructure. Passive air defense is also retained in both Army and joint doctrine. The Army's

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[90] Shlapak et al., 129-135.

[91] Samuel R. Bethel, "Sustainment in an Anti-Access/Area-Denial Environment," *Army Sustainment*, (January-February 2016): 12-16.

[92] David A. Shlapak et al., 129-130.

[93] Bethel, 12-16.

principal publication on protection focuses on the more tactical aspects of passive defense, but JP 3-01, *Countering Air and Missile Threats*, discusses planning for passive defense in detail.[94]

Passive defense at Remagen contributed to the preservation of US forces at the bridgehead, and the preservation of the bridgehead itself. Given the challenge posed to active defenses by unmanned systems, passive defense remains important as a mitigation if not more so. Fortunately, the lesson of passive defense from World War Two remains within the US Army, even if somewhat atrophied in its training.

Shaping Conditions

One of the most immediate actions taken by the Allies upon the capture of the Ludendorff Bridge was the establishment of an Inner Artillery Zone. While this declaration removed immediate air support to the ground forces at the crossing, it enabled AAA to engage freely without establishing identification.[95] This was particularly significant at night when visual identification was all but impossible. The US Army Air Corps still contributed to the battle in the air by attacking Luftwaffe airfields, degrading the number of sorties the Germans could fly against the bridgehead.[96]

Overcoming the challenge to identification through deconfliction remains a valid lesson against the unmanned threat, and with incidents as recent as 2003, fratricide remains a valid concern.[97] With reduced early warning, similar to conditions at Remagen, identifying unmanned

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[94] Army Doctrine Reference Publication (ADRP) 3-37, *Protection* (Washington, DC: Government Printing Office, 2012), 1-13, 4-2, 4-4; Joint Publication (JP) 3-01, *Countering Air and Missile Threats* (Washington, DC: Government Printing Office, 2012), I-4, I-5, V-19-V-23.

[95] Semmens.

[96] Hammel, 455-460.

[97] Office of the Under Secretary of Defense For Acquisition, Technology and Logistics, *Patriot System Performance Report Summary* (Washington, DC: Defense Science Board, 2005), accessed 22 February 2016, http://www.acq.osd.mil/dsb/reports/ADA435837.pdf.

aircraft and cruise missiles is more difficult than identifying manned counterparts. The joint force likewise can mitigate the unmanned challenge through procedural identification linked to airspace or classification of a target as unmanned.

However, the deep fight executed by Army Air Corps does not translate as easily. The Ninth Air Force, excluded from the Inner Artillery Zone, struck eastwards against the airfields supporting the Luftwaffe rather than intercept them in the air immediately above the bridgehead.[98] Unlike the German aircraft, unmanned systems enjoy a relative advantage in survivability. As previously discussed, UAS and cruise missiles are typically mobile, easy to hide, and not restrained to airfields.[99] They are more difficult to target with offensive air.

Although not constrained to airfields, unmanned threats still have requirements the United States can deny through other means. UAS and cruise missiles both rely on access to the electromagnetic spectrum either for datalink control or for precise navigation. Just as barrage fire denied airspace to German jets, electronic warfare and jamming are capable of preventing UAS from receiving control inputs or transmit sensor outputs.[100] Denying satellite navigation to both UAS and cruise missiles may reduce the accuracy of either in an attack role if the system lacks other sophisticated guidance.

Electronic warfare can also help address the challenge of detection and identification, as detection is not limited to radar. Most unmanned aircraft are directly controlled through electronic datalinks. Despite a small radar cross section, the signals broadcast by UAS are still detectable by electronic sensors. Datalinks can potentially be exploited as an alternate means of early warning

[98] Hammel, 455-460.

[99] Mahnken, 32.

[100] Yochim, 70-73.

and identification.[101] Although less useful against cruise missiles and autonomous drones, electronic warfare does offer an advantage to detect and identify UAS.[102]

The US Army and Air Corps shaped conditions at Remagen to both facilitate US active defense and diminish Luftwaffe capability. The same opportunities exist against unmanned systems if in a slightly different form. Deconflicting airspace and the use of electronic warfare can help offset the relative advantage of unmanned systems in detection and identification. Similarly, electronic warfare can mitigate the relative advantage in survivability by exploiting unmanned vulnerabilities in the electromagnetic spectrum.

These capabilities already reside in Army formations. Airspace management is a function present in headquarters at the brigade level and above.[103] Electronic warfare also is present in maneuver formations. Procedural identification of UAS or cruise missiles tied to airspace or electronic signature both provide options to facilitate ground-based defense against unmanned threats.[104] Similarly, incorporating electronic warfare into a fully integrated air defense system could allow the joint force to diminish the effectiveness of UAS and cruise missiles against the US Army and other targets.

Summary

There are three major lessons from the European theater regarding operations under air threat displayed at Remagen: organization of active defense, employing passive defense, and shaping conditions to favor friendly defenses while diminishing enemy capability. These lessons

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[101] F. Patrick Filbert and Darryl Johnson, "Joint Counter Low, Slow, Small, Unmanned Aircraft Systems Test," *Fires*, (July-August, 2014), accessed 18 August 2015, https://www.dvidshub.net/publication/issues/22456.

[102] Judnic and Burke, 14-17.

[103] Army Techniques Publication (ATP) 3-01.50, *Air Defense and Airspace Management (ADAM) Cell Operations* (Washington DC: Government Printing Office, 2013), 1-1-1-5, 2-1-2-6.

[104] Filbert and Johnson.

translate to the emerging unmanned threat to varying degrees. Organization of active defense at multiple echelons appears to remain as valid today as it did in 1945. Passive defense is even more important based on the relative disadvantages of unmanned aircraft and their vulnerability to passive countermeasures. Shaping conditions to favor friendly forces remains valid, but the methods employed in 1945 do not directly translate. While the capability for passive defense has been retained, the ability to echelon air defense is no longer feasible in the US Army active component. Shaping conditions through offensive counterair and airspace management should be supplemented with the integration of electronic warfare to exploit the vulnerabilities of unmanned threats.

Conclusion

Unmanned threats perform the same roles as manned aircraft, but do not pose the same risk. Removing the pilot from the airframe offers significant advantages that affect the probability and severity of attack through the air. In particular, reducing cost and removing the risk to crew fundamentally changes the threshold at which an adversary action through the air is acceptable, even against a dominant air force. While the contemporary and counterfactual case studies regarding Hezbollah’s and China’s use of unmanned systems do not provide a precise evaluation of the risk of these emerging threats in future conflict, they both support a resulting increase to both probability and severity. These cases suggest the unmitigated risk from air attack is no longer negligible to US land forces and their mission.

The historical case study of Remagen offers insights into the capabilities required for a ground force like the US Army to operate under threat of air attack that unmanned technology allows. First, since unmanned threats permit less early warning, active air defense should be organized at multiple echelons, allowing for immediate defense of maneuver units using an organic capability, while still allowing air defense from higher echelons to defend rear areas or mass at decisive points as needed.

The second capability required at Remagen was passive air defense both in the form of an immediate capability to repair and recuperate damage from attack, and also planning that allows for dispersion, redundancy and dislocation of strategic assets in order to reduce vulnerability through the air. Given the relative disadvantages of unmanned aircraft and cruise missiles, passive defenses are particularly effective. The importance of passive air defense, although not currently emphasized, is still retained in US Army materiel, organizations, and doctrine.

The third lesson from Remagen is the effectiveness of shaping of conditions through airspace deconfliction and offensive counterair. By establishing an Inner Artillery Zone, AAA was free to fire on enemy aircraft without the requirement for sometimes difficult identification. By denying airspace and airfields to the Luftwaffe, US forces degraded the German ability to generate sorties against the bridgehead. Integrating electronic warfare into the air defense system can similarly be used to degrade unmanned performance by denying vital access to the electromagnetic spectrum.

There are caveats to consider with these recommendations. While echeloning air defense with maneuver units would address the immediate threat posed by unmanned threats, it must be balanced with other requirements. The US Army is expeditionary in nature. Units must be rapidly deployable. Expanding maneuver formations with air defense or electronic warfare would also increase the lift required to deploy Army formations to distant theaters. Increased active defense would come at a cost of other enablers or aggregate combat power needed to counter other threats. While this might be appropriate against an unmanned fleet the size China intends to acquire, it might not be suitable against a different adversary with different capabilities.

Furthermore, as unmanned technology continues to develop, there is a shelf life associated with these conclusions. The availability and capabilities of unmanned systems have improved considerably over recent years and will continue to improve. While this study concludes UAS currently are not used in novel new roles compared to manned aircraft, this may prove false in the future. The roles, advantages, and disadvantages of unmanned aircraft and cruise missiles that form the foundation of this analysis are all subject to change.

While unmanned systems perform many of the same roles as manned aircraft, removing the pilot from an airframe offers advantages that significantly increase the possibility of an adversary interfering with the US Army and its mission through the air. With the proliferation of unmanned technology, the risk of air attack is no longer insignificant. Many of the possible mitigations of this risk have been retained in some form since the Army last operated under aerial threats. But some lessons have been forgotten, or are in need of adjustment. There are ways the US Army can adapt to better operate under the emerging unmanned threat.

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